IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

AMPEX CORPORATION, Plaintiff, v. EASTMAN KODAK COMPANY, ALTEK CORPORATION and CHINON INDUSTRIES, INC., Defendants.	)	C.A. No. 04-1373-KAJ **REDACTED**

APPENDIX TO DEFENDANTS' REPLY BRIEF IN FURTHER SUPPORT OF THEIR MOTION FOR SUMMARY JUDGMENT OF NONINFRINGEMENT

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Table of Contents

United States Patent [19]

Lloyd et al.

[11] 4,131,919

[45] Dec. 26, 1978

[54] ELECTRONIC STILL CAMERA

[75] Inventors: Gareth A. Lloyd; Steven J. Sasson, both of Rochester, N.Y.

[73] Assignee: Eastman Kodak Company, Rochester, N.Y.

[21] Appl. No.: 798,956

[22] Filed: May 20, 1977

[51] Int. Cl.[2] H04N 5/79

[52] U.S. Cl. 360/9; 360/35; 358/127; 358/134; 358/213

[58] Field of Search .... 360/9, 10, 8, 35, 33; 179/2 TV; 358/127, 134, 213, 85, 133, 78

[56] References Cited

U.S. PATENT DOCUMENTS

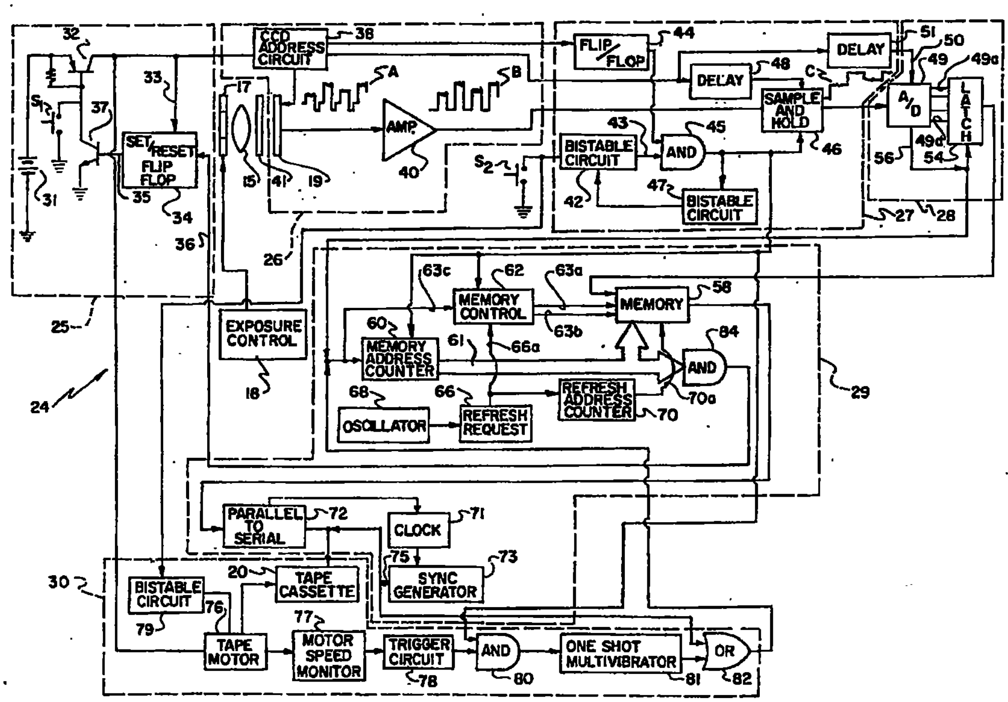
3,858,232	12/1974	Boyle	357/24
3,911,467	10/1975	Levine	358/213
3,962,725	6/1976	Lemke	360/37
4,016,361	4/1977	Pandey	360/9
4,057,830	11/1977	Adcock	360/35

Primary Examiner—Bernard Konick
Assistant Examiner—Alan Faber
Attorney, Agent, or Firm—D. P. Monteith

[57] ABSTRACT

Electronic imaging apparatus, preferably an electronic still camera, employs an inexpensive information-recording medium such as audio-grade magnetic tape for "capturing" scene images. The camera includes a charge coupled device comprised of an array of photo-sensitive elements which form a charge pattern corresponding to an optical image projected onto the elements during an exposure interval. A charge transfer circuit converts the charge pattern into a high frequency pulsed electrical signal immediately following the exposure interval to remove the charge from the device in a short period of time to maintain unwanted "dark current" at a low level. Each pulse represents the image-forming light projected onto a particular photo-sensitive element. A high speed analog-to-digital converter converts these pulses to multi-bit digital words in real time. A digital buffer memory temporarily stores these words, then retransmits them at a rate that is compatible for recording on the audio-grade tape. The image can be displayed on a conventional television receiver by reading the recorded words from the tape and converting them to a format compatible with the signal-receiving circuitry of the television.

8 Claims, 4 Drawing Figures



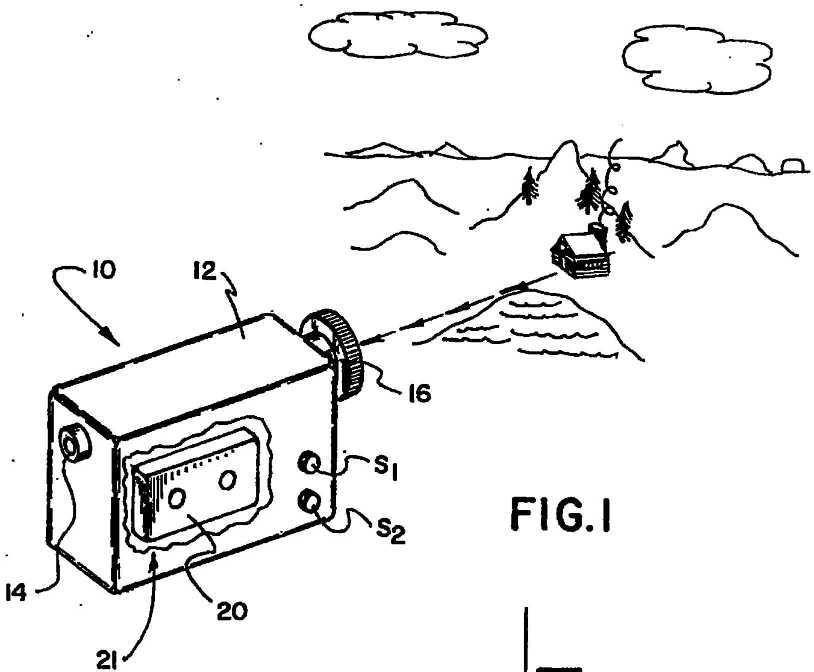


FIG.1

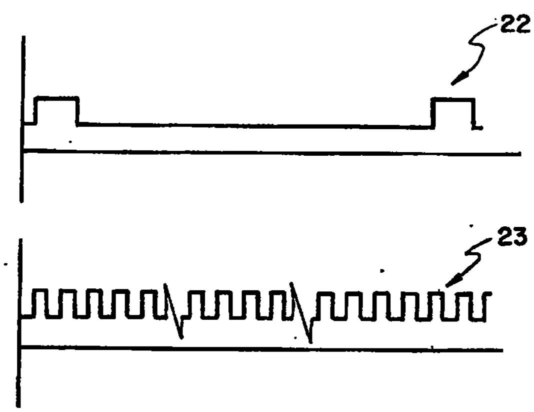


FIG.3

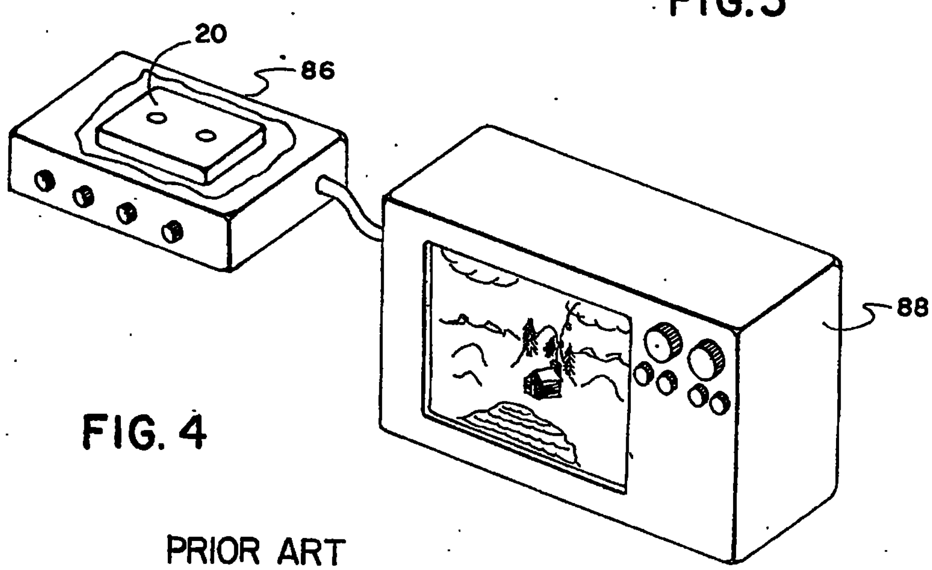


FIG. 4

PRIOR ART

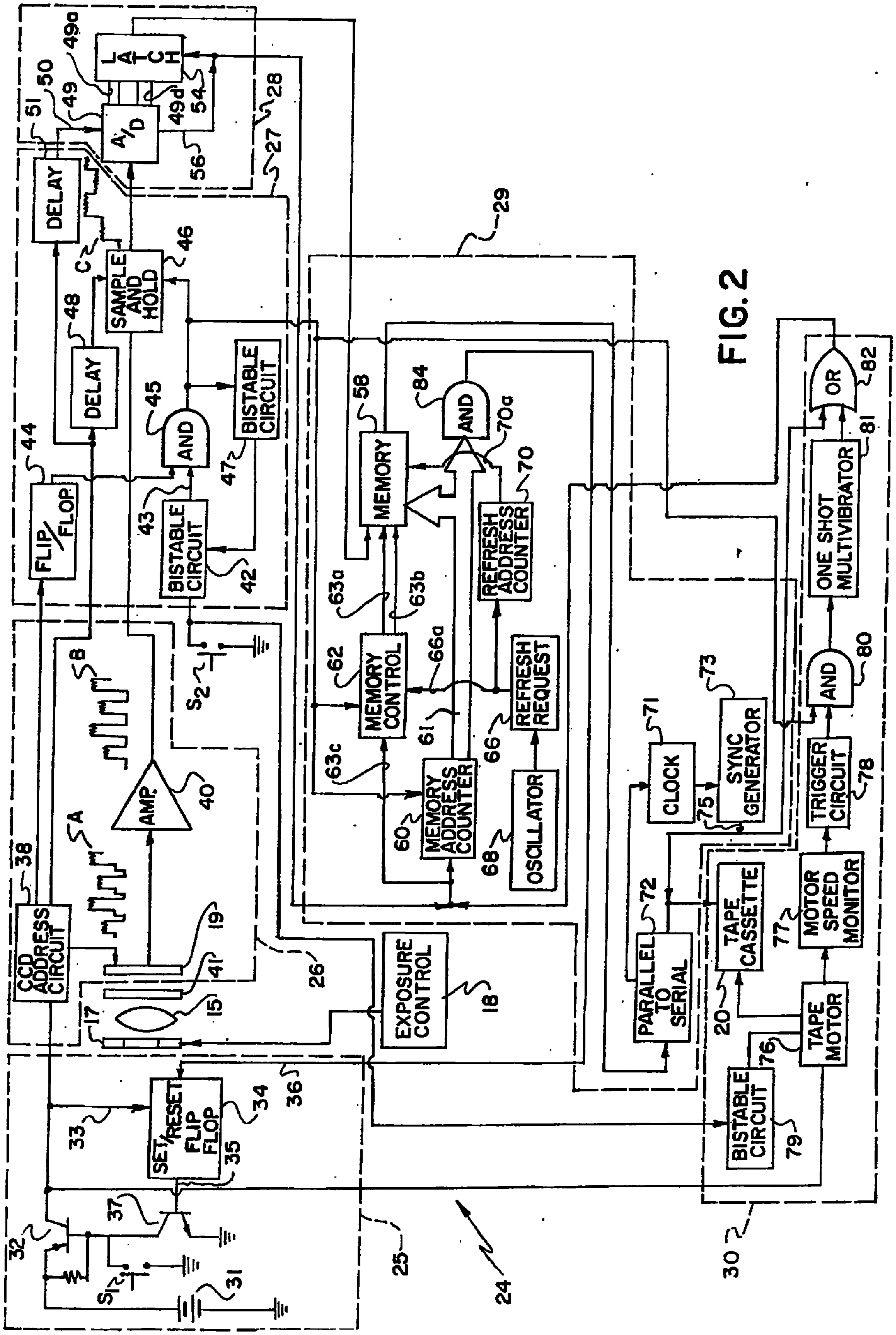

LATCH
A/D
DELAY
SAMPLE AND HOLD
DELAY
FLIP/FLOP
AND
BISTABLE CIRCUIT
BISTABLE CIRCUIT
AMP.
CCD ADDRESS CIRCUIT
SET/RESET FLIP FLOP
EXPOSURE CONTROL
MEMORY
AND
REFRESH ADDRESS COUNTER
MEMORY CONTROL
MEMORY ADDRESS COUNTER
REFRESH REQUEST
OSCILLATOR
CLOCK
SYNC GENERATOR
PARALLEL TO SERIAL
TAPE CASSETTE
MOTOR SPEED MONITOR
TAPE MOTOR
BISTABLE CIRCUIT
TRIGGER CIRCUIT
AND
ONE SHOT MULTIVIBRATOR
OR

FIG. 2

ELECTRONIC STILL CAMERA

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates in general to electronic imaging apparatus and in particular, to an electronic still camera that employs a non-volatile reuseable storage medium for recording scene images.

Description of the Prior Art

Conventional cameras employ a shutter for exposing for a limited duration photographic film located at a film exposure plane. Film processing solutions are required to produce a visible image of trhe photographed scene. As is well known, processed photographic film may not be reused.

Recently, considerable effort has been given to the development of solid-state elements for imaging purposes. Such elements offer an advantage over photographic film in that, theoretically, they can be reused any number of times for imaging.

A solid-state imaging element of the type known as a charge transfer device can include a semiconductive substrate doped with majority carriers and covered with a thin insulating film upon which is located an array of electrically conductive electrodes. A depletion region or potential well is formed within the semiconductor under electrodes biased by a voltage of the proper polarity. The use of a charge transfer device involves the basic concept of forming a charge pattern consisting of packets of minority carriers in the potential wells. In the course of an optical imaging process, photons incident upon the semiconductor generate minority carriers within these potential wells in proportion to the amount of light impinging upon the semiconductor in the near vicinity of each well. These packets can be transferred through the semiconductor by sequentially biasing the electrodes. The potential wells effectively "move" through the semiconductor sweeping the minority carriers along within the wells. At an appropriate location these packets may be detected, for example, by removing them sequentially from the semiconductor by means of a reverse-biased diode coupled to transfer electrodes. An arrangement for read-out of information from a charge transfer device is disclosed in *IEEE Transactions On Electron Devices*, Vol. ED-20, No. 6, June 1973, in an article entitled "Interlacing In Charge Coupled Imaging Devices", by Carlo H. Sequin.

As with conventional photographic film, to obtain a scene image having a proper contrast, the imaging element must not be overexposed, or, in other words, the potential wells must not be saturated with minority carriers during the exposure interval. However, even in the absence of illumination, the regions constituting the potential wells tend to saturate with the passage of time by means of the thermal generation of minority carriers. Carriers generated in this manner constitute an unwanted signal commonly known as a "dark current". It is important that this signal be only a small fraction of the signal produced by incident illumination, particularly if the dark current is non-uniform over the imaging area.

U.K. Pat. No. 1,440,792, entitled ELECTRONIC STILL PICTURE CAMERA, and U.S. Pat. No. 4,057,830 which corresponds thereto and is entitled Electronic Photography System, disclose a camera for electronically recording "stop-action" or still pictures

that includes a charge transfer device, and recording apparatus that employs an inexpensive information-recording medium which is non-volatile and reuseable, such as a magnetic tape, disc or drum. The camera also includes a conventional shutter mechanism for exposing the transfer device to reflected scene light for a duration related to scene brightness. The rate of read-out of the signals produced by the charge transfer device is synchronized with the speed of the recording apparatus since the transfer device output is connected directly to the input of the recording apparatus. These signals are read-out at a relatively slow speed to record a scene image on the storage medium that is employed. It takes approximately one second to output scene information from the charge transfer device. For "stop-action" photography an exposure interval of approximately 1/20 second or less is needed. Accordingly, the charge transfer device is used both for imaging and until scene information is read-out, for data storage.

That camera suffers from the disadvantage that the charge pattern related to the incident illumination will be adversely affected by thermally generated minority carriers. Not only would it be expected that significant dark current would be produced with a 1-second storage interval, but it could also be expected that the "dark current" would be nonuniform. This is because the storage interval for any potential well, and accordingly the number of thermally generated minority carriers in that well, is dependent upon whether or not that potential well is among the first or the last to sweep through the semiconductor to an output transfer electrode. Furthermore, saturation of some potential wells may occur if too many minority carriers are thermally generated. Excess minority carriers would spread to adjacent potential wells to be added to minority carriers in non-saturated potential wells.

SUMMARY OF THE INVENTION

An object of the present invention is to provide improved electronic imaging apparatus.

In accordance with the above object, the present invention is addressed to an electronic still camera which includes a solid-state imaging device that produces a charge pattern corresponding to an optical image projected onto an imaging surface during an exposure interval. Charge transfer means converts such charge pattern into a high frequency pulsed electrical signal within a relatively brief time after termination of the exposure interval. Electrical signal transforming means receives data corresponding to this electrical signal in real time, then retransmits such data at a substantially slower rate to recording apparatus. This slower data rate permits recording of signals corresponding to the optical image on an inexpensive recording medium such as audiograde magnetic tape.

The invention, and its objects and advantages, will become more apparent in the detailed description of a preferred embodiment presented below.

BRIEF DESCRIPTION OF THE DRAWINGS

In the detailed description of a preferred embodiment of the invention presented below, reference is made to the accompanying drawings in which:

FIG. 1 pictorially represents an electronic still camera in accordance with the teachings of the present invention;

FIG. 2 is a schematic block diagram of a solid-state image sensor, and signal processing circuitry in the camera of FIG. 1;

FIG. 3 is a drawing of waveforms to help explain the operation of the solid-state image sensor and signal processing circuitry of FIG. 2; and

FIG. 4 is a perspective view of apparatus for displaying pictures of scenes recorded by the camera of FIG. 1.

DESCRIPTION OF A PREFERRED EMBODIMENT

The present description will be directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the present invention. It is to be understood elements not specifically shown or described may take various forms well known to those having skill in the art.

There is shown in FIG. 1 of the drawings an electronic still camera, designated generally by the numeral 10. As with conventional still cameras of the type that employ photographic film for "capturing" light from a scene being photographed, camera 10 includes a housing 12, a viewfinder 14, and a taking lens 15 (shown in FIG. 2) located within a lens barrel 16. A diaphragm mechanism 17 (shown in FIG. 2), coupled to an exposure control circuit 18 (also shown in FIG. 2), forms a variable aperture aligned with lens 15 to control the amount of scene light transmitted through the lens. Diaphragm control is automatic and is provided by means, well known in the art, that controls the lens aperture in accordance with the intensity of reflected scene light, the control being effected by the current produced by a photoconductive element, such as a photocell, of circuit 18. Photoconductively controlled diaphragm mechanisms are well known in the art and are disclosed in several patents, one of which is U.S. Pat. No. 3,962,707 filed in the name of F. M. Galbraith, Jr. and commonly assigned herewith.

Unlike conventional still cameras that employ photographic film, camera 10 employs a solid-state image sensor 19 (shown in FIG. 2), located at the focal plane of lens 15, and a record storage medium, such as, for example, reuseable magnetic tape, for recording electrical signals corresponding to scene images projected onto the imaging surface of sensor 19. The tape may, for example, be located in a magnetic tape cassette 20, which is located in a cassette-receiving chamber 21. Chamber 21 is accessible through a camera door (not shown) and includes means (also not shown) for removably mounting the cassette 20 in the chamber. Cassette 20 is adapted to be connected to suitable data retrieval apparatus, as referred to hereinafter, to obtain visual displays of recorded scenes.

Sensor 19 constitutes a charge transfer device and, in particular, is a charge coupled device (CCD), which produces a pattern of charge carriers that is an analog representation of an optical image focused onto an imaging surface of the CCD. As is known in the art, a CCD may include a silicon substrate covered by oxidized silicon, with an array of closely spaced conducting pads on the silicon dioxide surface. The pads serve as gate electrodes and may, for example, be formed by selectively doping a layer of transparent polysilicon material. These gate electrodes are interconnected in rows (or columns), which are electrically connected to both a CCD address circuit for sequentially applying gate electrode voltages, and to a data readout register.

When a CCD is used as an imaging device, charge carriers are produced by light quanta absorbed in the silicon, the number of carriers being proportional to the amount of radiant energy reaching the silicon. During the so-called "integration time", comparable to the exposure time in conventional camera art, the CCD address circuit applies voltages to the gate electrode array to provide a pattern of photosites having potential wells which attract charged minority carriers. A charge pattern will form in the potential wells under the various photosites nearest to where the charges are produced. The number of charge carriers which accumulate in each potential well during the integration time is proportional to the amount of radiant energy reaching that well and this, in turn, is proportional to the radiation intensity and the duration of the integration time. Thus, a spatial pattern of carriers corresponding to an optical image is produced by the CCD. For further, more detailed descriptions of CCD's, reference is made to one of the numerous publications on such devices, U.S. Pat. No. 3,858,232, entitled INFORMATION STORAGE DEVICES, the disclosure of which is incorporated herein by reference.

By the proper manipulation of voltage potentials to the interconnected rows (or columns) of electrodes following this integration time, this charge pattern can be shifted to one point of the CCD, where, by means of a suitable output connection the charge collected can be removed sequentially into the aforementioned data readout register. This stream of charge then constitutes an electrical current which is an analog replica of the light projected onto the CCD. Such a current is caused to flow through an output load to generate a train of voltage pulses, each pulse representing one small area of the projected image with pulse amplitude being proportional to the amount of radiation reaching a particular photosite.

With our presently preferred CCD apparatus, an image is formed in two separate, interlaced fields, each field containing one-half the total number of photosites. Photosites are formed in the first field for 25 milliseconds (ms), then photosites are formed in the second field for the next 25ms interval, the total "exposure interval" being 50ms. While charge packets are formed in the second field, the charge pattern in the first field is read out and converted to a train of voltage pulses, the pulse repetition rate being inversely proportional to the interval used for read-out. For detailed descriptions of CCD interlacing techniques and apparatus, reference is made to U.S. Pat. No. 3,911,467, entitled INTERLACED READOUT OF CHARGE STORED IN CHARGE-COUPLED IMAGE SENSING ARRAY, and to the aforementioned article by C. H. Sequin.

Since the fields are interlaced, scene information is reorganized so as not to be presented for display in the same interlaced timing format. Apparatus for data reorganization is provided by the aforementioned data retrieval apparatus.

A type 201 CCD, manufactured by the Fairchild Camera and Instrument Company (FCI), includes a 100 × 100 photosite array. For that CCD, an optical image may be represented by a CCD output pulse train of 10-thousand pulses. Four pulses of such a train are denoted A in FIG. 2.

Two of the clock signals associated with CCD 19 are illustrated schematically in FIG. 3. Waveform 22 constitutes a master clock signal and is used to signal the beginning and end of a pulse train that represents an

image projected onto the CCD during one "exposure interval", e.g. 50ms. For a pulse train duration of, for example, 50ms, waveform 22 would be a 20 cycle per second (Hz) signal. (The duration of such a pulse train and an exposure interval need not be the same.) Waveform 23 is a high-frequency signal that is used to synchronize the operation of signal processing circuitry, denoted generally 24, with the occurrence of each pulse in the CCD output signal, as explained in detail hereinafter. If 10,000 pulses are produced in a 50ms interval, waveform 23 would be a 200-thousand Hz signal.

In accordance with our invention, light from a scene to be recorded is "captured" electronically in the following manner. A camera operator first actuates a power control member to apply electrical power to circuitry 24. At that instant, CCD address circuits cause the CCD to commence producing its pulsed output signals, a pulse train being produced for each exposure interval. In addition, light-sensitive exposure control circuit 18 positions diaphragm 17 to form a lens aperture in accordance with the level of ambient light. No CCD output pulse train is processed, however, until a second control member is actuated. Once such actuation occurs, a CCD output signal, representing an optical image projected onto an imaging surface during one exposure interval, is processed. Each CCD pulse for the interval is digitized in real time to form a digital word, i.e., a total of 10,000 digital words for the aforementioned type 201 CCD, and such words are advantageously stored in a high-speed buffer memory. These digital words are sequentially retransmitted, preferably, after the buffer memory receives the last digital word, at a rate that is substantially lower than the CCD pulse output rate. This low signal rate permits inexpensive recording apparatus to be used for recording scene information.

With our presently preferred camera apparatus, the scene information for the first field is stored in the buffer memory during the time the charge pattern for the second field is formed. Accordingly, the total time used to "capture" a single scene image and store it in the buffer memory is approximately 75ms. Scene information is transferred from the buffer to the recording apparatus in approximately 23 seconds.

With this arrangement, CCD dark current is maintained at a low level since the CCD is not employed for information storage in the same sense as is the imaging device employed in the electronic camera disclosed in the aforementioned U.K. patent 1,440,792. Furthermore, there is no need to employ expensive recording apparatus, such as broadband video apparatus. In fact, recording apparatus having relatively slow recording or data-write speeds, such as for example, audio-grade magnetic recording apparatus, may be utilized to reliably and accurately record information transmitted from the buffer memory.

It shall be understood that an "integration interval" and the time used to output scene data from the CCD for one field need not be predetermined nor of the same duration. For example, an integration interval and/or exposure interval could be controlled by a light-sensitive integrating circuit, the control being effected by the time required to charge a capacitor to a predetermined level by a current through a photoresistive element. The capacitor and photoresistor constitute an integrating circuit having a variable time constant related to the intensity of the light impinging on the photoresistor. Read-out of scene data from the CCD could, for example, commence in timed relation to the capacitor being charged to such level Photoconductively controlled timing circuits are well known in the art and are disclosed in many patents, one of which is U.S. Pat. No. 3,672,267, entitled SEQUENTIAL CONTROL FOR CAMERA DIAPHRAGM AND SHUTTER, and commonly assigned herewith.

An important feature of our invention is, however, that read-out of the charge pattern for each field occurs rapidly so that the CCD is not employed for any significant period of time as a storage device.

Referring now to FIG. 2, there is shown a schematic diagram of signal processing circuitry 24 for obtaining still pictures of scenes imaged onto CCD 19. Circuit 24 includes generally a power control circuit 25, and image-sensor apparatus 26, including CCD 19, for producing a high frequency pulsed electrical signal corresponding to an imaged scene, each pulse in the signal having an amplitude proportional to the amount of light impinging on a particular photosite of the CCD. A circuit 27 constitutes an electronic shutter to control the signal produced by CCD 19 that is to be recorded. An analog-to-digital (A/D) converter circuit 28 converts in real time the signal transmitted by circuit 27 into multi-bit digital words. Buffer circuitry 29 functions to receive and temporarily store such words in real time, then transmits them at a rate that is substantially lower than the real time rate at which these words are loaded into the buffer. Circuit 24 also includes recording apparatus 30 having a data recording speed that is compatible with the rate that data is transmitted from buffer 29.

As with a conventional still camera that employs photographic film to obtain a "photograph" lens barrel 16 (FIG. 1) is pointed at a scene visible through viewfinder 14. Electrical power is provided for circuitry 24 from a battery 31 upon actuation of a momentary, push-button switch S_1 mounted on housing 12, as shown in FIG. 1. When switch S_1 is closed, the baseemitter junction of transistor 32 is forwardly biased to turn the transistor ON, and collector current flows to turn signal processing circuitry 24 ON. At the same time, a bias signal is produced on conductor 33 that is applied to a set-reset flip flop 34. When this happens, flip flop 34 assumes a set condition and produces at its output 35 a high-level voltage to thereby turn transistor 37 ON. When a voltage signal above a predetermined level is applied to its input 36, flip flop 34 switches into its reset condition and its output 35 produces a low-level voltage to turn transistor 37 OFF. When this occurs, with switch S_1 in its open position, transistor 32 is turned OFF to remove electrical power from circuitry 24.

Image-sensor apparatus 26 includes a CCD address circuit 38, which causes signals 22 and 23 in the form of clock pulses to be applied to CCD gate electrodes in a known manner to produce the aforementioned pulsed electrical output signal. This output signal is produced during a brief interval immediately following the integration time for each of the aforementioned two fields so that dark current is maintained at a low level. In a preferred embodiment, FCI type 201 CCD is employed using a 25ms integration time and 25ms readout interval for each field, the total readout interval being 50ms for the signal representing an optical image.

Image-sensor apparatus 26 also includes a video amplifier 40 to filter out noise in the CCD output signal, as illustrated diagrammatically by the signal waveform B at the output of amplifier 40. Since CCD's typically are sensitive to infrared (IR) radiation, image-sensor appa-